Extracting the Low-income Characteristics Using PCA for Socio-economic Vulnerability Masuring in Bangkok, Thailand

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Abstract

Due to urbanization and urban growth, the developing country also generates the major driving force of slum / low-income settlements and conditions. In particular, Principle Component Analysis (PCA) techniques are interpreted on independent variables of statistical approach. It was produced to identify source of Low-Income Settlement Characteristic (LISC) and results of different associations among the possibility of urbanization crisis in the Bangkok Metropolitan Region (BMR) of Thailand. The research result was extracted from a large data set using 22 well-known indicators under 6 components, comprising socio-economic vulnerability indexes. From the loading plots, the calculation of many indicators were indicating the strong correlation among these variables: (1) personal contribution, (2) living density, (3) expenditure estimation, (4) slum / low-income condition, (5) industrial sources, and (6) facility sources. Our finding, information indices represented a potentially useful measure for the low-income characteristic changes. Hence, the normalized indexes indicated the possible highlight sites of the vulnerability indices using spatial geographical settlements, makeing likely improvement and localization in construction of quality of life and urban planning level between similarly indices.

Keywords

Urbanization; Low-income Settlement Characteristics (LISC); Principle Component Analysis (PCA); Socio-economic Vulnerability Index; Bangkok Metropolitan Region (BMR)

Introduction

With the rapid urbanization occurring in many parts of the world, which has not only contributed to environmental problems, but also affected socio-economical development especially in developing countries, the urban growth rate of developing countries is twice as high as most of developed countries. The world population was projected to reach of 80% since 1970-2000, and the unprecedented urbanization rate is concerned with the inherent demographic processes via a natural growth and migration of rural-urban population (Hope, 1986). The initial attitude and response of Thailand as one of developing countries had been imposed for a long term due to the fast growing type of urban population was responsible for more than 50% of natural population in 1970-75 (Newland, 1980). These factors have affected the net income growth, which depends dominantly on offsetting factors. However, consequences were being associated with higher industrialization and productivity only a few years ago. In contrast, negative effects were experienced with the economic association and population of urban area, whose result of over-urbanization is extensively widespread unemployment and under-employment rate that is exceeded 25% in Latin America, Africa, and Asia in addition to many problems of lack of housing, accessibility of urban services, traffic congestion, and urban environmental pollution (Miro & Potter, 1980; Hope, 1986). In short, developing countries are moving into a stage of sharply increasing demographic transition, so the effectiveness was corrected in the economic model. It seems preferable to react more immediately to the definition of economic incentives than fertility of economic transformations (Backer & Morrison, 1999).

Uncontrolled and unplanned urban growth makes it difficult to provide residents with the services they desire, despite the current urban bias with respect to development expenditures and strategies. There are four main reasons for concern over the cost of (1) fiscal

of the rapid increasing demand for urban services, (2) high financial costs of international indebtedness for third world nations, (3) economic efficiency costs, and (4) equity for high subsidize of urbanization costs (Linn, 1982). The most common explained income inequality segmented the labor market into formal and informal sectors. The conformance standard of labor regulations and payment of taxes are determined across seven counties including Thailand (Mead & Morrison, 1996), as the housing priorities have not been able to given for fundamental demand. In the developing world, more than half of all informal sector employments lie on uncontrolled squatter settlements. This leads to overcrowding and steeply climbing house prices, which is usually regarded as the social solution products to slum dwellings/ low-income settlemen.

Behavioral economic models are expected to become more sophisticated demographic frameworks, one of which has been a combined approach to the low-income settlements as the main effects on urban planning and policy management in Bangkok Metropolitan Region (BMR), a capital of Thailand. More than 90% of new urbanites were located at facilities line of BMR by the explosive growth of population, low economic stages, and poor environment. However, governments have been forced the low-income settlements in response to their public policies and organization as National Housing Authority (NHA) and Community Organizations Development Institute (CODI). There provides and affords the land, housing and facility in low-price. Among the outputs of successful management, both potentials and limitations cost more time to controll and focus on ownership and participation process. Lastly, almost low-income settlements /slum dwellers were not only scattered on relatively small plots of land nearby CBD of BMR, but also were introduced into the main problems of comprehensive information and urban dynamic approaches as shown in the point pattern analysis using GIS technique (Shummadtayar and Kazunori, 2012) (Fig. 1).

The most important characteristic of urban area and low-income settlements should be argued that balancing sustainability urbanization in term of economic, social, environmental, political, and technology (Pugh, 1995). Therefore, the frist aim of this study was to consider the appropriate statistical methods for extracting the low-income settlement factors using principal component analysis (PCA), and later can examine the characteristics of low-income settlements in terms of socio-economical vulnerability indexes among the possibility of urbanization crisis occurring in Bangkok Metropolitan Region of Thailand. The principle component analysis (PCA) techniques are explained the independent variables of statistical approach from a large data set, indicating the strong correlation between them.

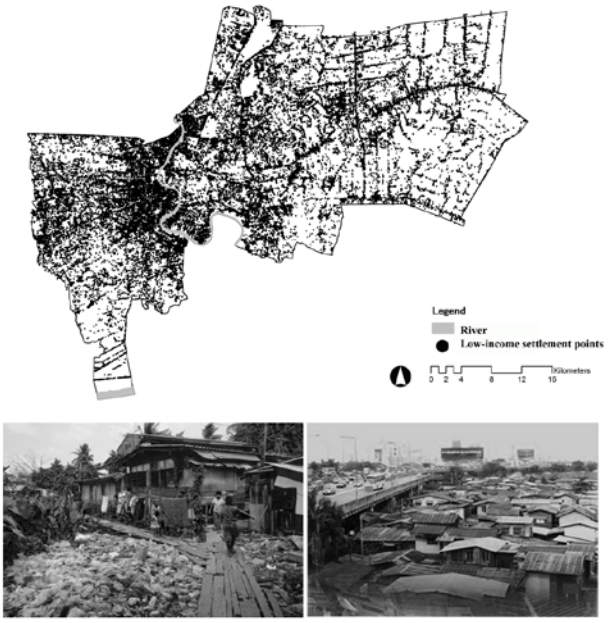

FIG. 1 THE LOW-INCOME AND SETTLEMENT POINTS IN 2009.
SOURCE: SHUMMADTAYAR ET AL., 2012.

Materials and Methodology

Study Area

The study area is located in Bangkok Metropolitan Region (BMR), a capital of Thailand, as shown in Fig. 2. There was established between 13o45′8″N and 100o 29′38″E, covering 1,568.737 sq.km. (606 sq. mi). BMR as the country's economic center is easy to seek employment, while there were not only harder to come by, but it was also less well acknowledged. This result has been growning rapidly over the part of rural income, including facilitating by good transportation, infra-structure, communication, services, etc. Much of the urbanization is providing the slum/low-income settlements and almost all of inhabitants are living in poor condition in many developing cities. In BMR, 196,354 households living were found the slum-dweller and squatter settlements in year 2000 (Pornchokchai, 2003) which is projected to increase to 225,440 households by 2009 (CODI, 2010). Moreover, World Bank (2006) reported that BMR has always been the fasted and most expended urbanized area. Indeed,

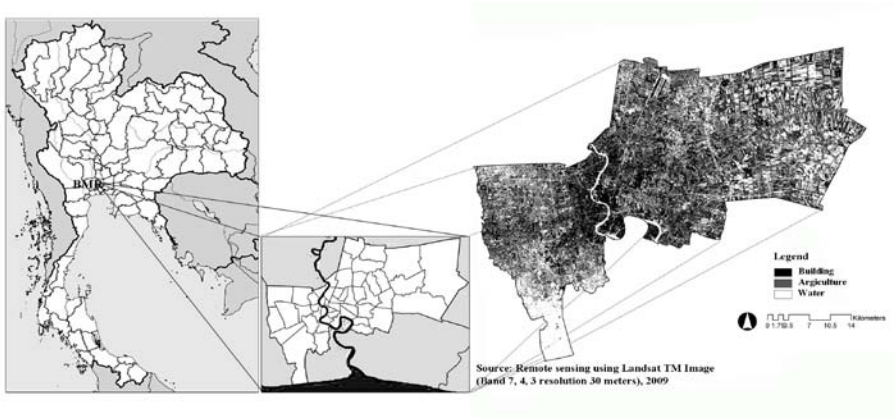

FIG. 2 BANGKOK METROPOLITAN REGION (BMR) AND URBANIZATION USING LANDSAT TM IMAGE 2009.

Fig. 3 shows growth in GDP per capital numbers (the circle of GDP maps) in 2002, which shows increased in economic activity from under 60% in 1970 to 72% in 2004, do not match the population growth.

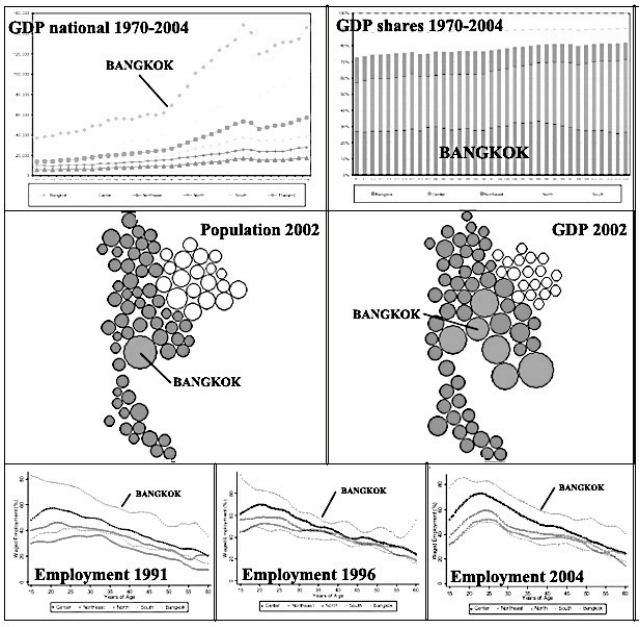

FIG. 3 ECONOMIC FEATURE OF URBANIZED AREA

IN BMR AND ITS VICINITY.

SOURCE: WORLD BANK, 2006.

Sampling and Analysis

Thus, this study focused the sampling area on Bangkok Metropolitan Region (BMR), Thailand. According to the collected data of independent indicators, there were carried out by the Strategy and Evaluation Department Bangkok Metropolitan Administration in 5 years (2001, 2003, 2005, 2007, and 2009), into aggregate vulnerability indices to provid an overview of socio-economical characteristics of BMR. Overall, 250 samples were separated by 50 districts of area study.

TABLE 1 TOTAL OF SPATIALLY DATASETS THAT IS USED IN SOCIO-ECONOMICAL VARIABILITY

Dataset Name	Description
Area Size	Area by districts
Total PP	Total number of population by districts
Male N	Number of male by districts
Female N	Number of female by district
PP Density	Density of Population by district per area
Household N	Number of household by district per unit
HH Density	Density of household unit per area
Slum PP	Number of population who live in slum/ low-income settlement
Slum Families	Number of family who lie on slum/ low-income settlement
Slum HH	Number of slum/ low-income settlement per household unit
Slum HH Den	Density of slum/ low-income settlement per area
Expenditure BG	Index of the population expenditure budget per capital
Property Taxes	Index of house and building property taxes per capital
Land Val. Taxes	Index of local development taxes per capital
Signboard Taxes	Index of signboard taxes per capital
Factories N	Number of industrial factories permission per unit
Capital Fac.	Index of factories production per capital
Labors Fac.	Number of labor's factories per person
Garbage Total	Amount of garbage total per tons
Residential Area	Total of residential area by districts
Commercial Area	Total of commercial area by districts
Industrial Area	Total of industrial area by districts
Hospital Area	Total of hospital area by districts
Education Area	Total of education area by districts
Region Area	Total of region area by districts

However, the large suites of individual indicators are difficult for measuring the low-income environmental vulnerability index changes of spatial settlement, which is constructed in a quality of life and urban planning level. The choice of the trade-off between a total of 250 samples of 25 variables collected by the strategy and Evaluation Department of BMR, depending on the priority is extracted from the composite of low-income settlement characteristics. The normalization of data is considered to guide policy tool for planning concern in terms of causes and impact of socio-economical factors across urban environmental changes, as shown in Table 1.

Principle Component Analysis (PCA)

Principal Component Analysis (PCA) is a descriptive statistic tool used in environmental studies for easily interpreted hidden complex and determined relationships among the observed variables. PCAs extracted a small number of latent factors, while retaining important information and representing variables of the maximum variability in data index. PCA is aimed at finding a quantification of variable that examined the observed grouping and properties of the inherent pattern of individual objects with loading/ score plot. In this study, PCA is useful in reducing data mathematical that correlated variables into a new set of orthogonal variables called principle components (PCs). Their were calculated based on the procedure to diagonalize and find the eigen vectors/ eigen values of the correlation matrix (Hair et al., 1987; Shiva and Khare, 2003) equal to or greater than one. PCA results will vary considerably depending on whether it is the covariance or correlation matrix. Moreover, the Varimax with Kaiser Normalization was loading the PC across variables for each factor used as the maximized rotation method by minimizing the number of large and small coefficients (Richman, 1986). The first few Eigenvectors (or PC1) account for the maximum total variability of the data set that is associated with the largest eigen value and represents the linear combination, which retained with an eigen values greater than one (Eder, 1989). The second PC explains a maximum variability, which is not accounted for PC1 and other PCs. The scores were estimated as follows:

$$PC_{ij} = \sum_{k=1}^{m} W_{ik} X_{kj} \quad (1)$$

where PC_{ij} is the PC score for the jth object on the ith component, w_{ik} is the loading of the kth variable on the ith component, and x_{kj} is the standardized value of the kth variable for the jth observation.

In addition, Kaiser–Meyer–Olkin (KMO) and Bartlett's Tests of Sphericity were used to examine its validity (Zhou et al., 2007) and assessed to the appropriateness of factor analysis for the variables. The overall Measure of Sampling Adequacy (MSA) for the set of KMO variables, which exceeds the minimum requirement of 0.50 for overall MSA, indicates that PCA may be useful for the dimensionality reductions. All principal factors extracted from the communality representing the proportion of the variance for each variable should be 0.50 or higher, and the cumulative proportion of variance criteria also satisfies the criterion of explaining 60% or more of the total variance.

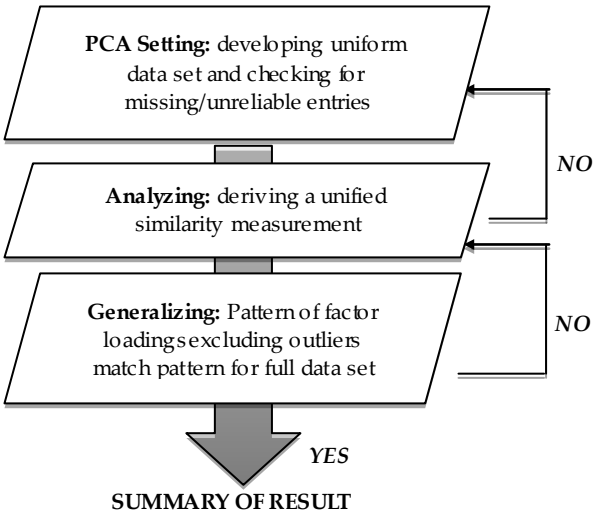

FIG. 4 THE FLOWCHART OF SOCIO-ECONOMIC DIVISION OF BMR

In addition, the socio-economical vulnerability is presented by the eigenvalues of component and the shape of the loading plots should not be less than 1.0, the original variation of proportion variables explained by Kaiser's rule of thumb (Griffith et al., 2000). The PCs loading was defined by the component of each individual vulnerability indicator based on the shape of scree and subjective judgment. According to the extracted process of PCA, division was applied successfully in the large multivariate scale for setting of variables, and adapting to concentration level in other area. In this paper, PCA data is performed by using SPSS statistical software as following in Fig. 4, if YES, it would pass into the next-step, which can be re-run factor analysis, excluding outliers. If NO, it may not be a pattern of factor loading match for full data

set, and it should be set the first random seed and rerun the compute factors. For finally vulnerability index, the standardized values are represented by the principle component scores between a range of 0-1, which is normalized of the least vulnerable (0) and the most vulnerable (1) grid square to allow direct comparison in dataset (Abson et al., 2012).

Results and Discussion

The analytical results of PCA for the mental concentration in the socio-economic variables were performed using SPSS statistical software. The Kaiser's criteria (Kaiser, 1958) retained the rotation method of Varimax with Kaiser normalisation to examine its validity of Kaisere-Mayere-Olkin (KMO) and Bartlett's sphericity test, which were 0.741 and 7506.135 ($p<0.05$), respectively, suggesting that the useful dimensionality variables were suitable for PCA analysis, as shown in Table 2.

TABLE 2 KMO AND BARTLETT'S TEST

KMO Measure of Sampling Adequacy	.741
Bartlett's Test of Sphericity	7506.135 210 .000

Complex structure occurs when the communality is the variance proportion of a particular item due to common factors (shared with other items) in each item, therefore, the respective item is total variance minus the communality (Jonhson and Wichern, 2008). In this PCA solution: four factors as Capital Fac., Commercial Area, Education Area, and Industrial Area, are accounted as the communality value for each variable that is less than 0.05, which should be removed from analysis. This factor solution found that 21 communality factors are estimated for all mentals (Table 3).

The highest communalities were extracted at 90% for Area size, total PP, male N, female N, PP density, HH density, slum PP, slum families, slum HH, factories N, and labors Fac. The lowest communalities were extracted at 50% for expenditure BG, and residential area. Overall, discussion on mental concentrations should be examined to identify variables that have complex structure.

With PCA-driven reult in the low-income characteristic model, the socio-economic variables in BMA were described with 6 components. Six significant PCs were retained for the relative

TABLE 3 COMMUNILITIES OF SOCIO-ECONOMICAL VULNERABILITY

Variables	Initial	Extraction
Area Size	1.000	.943
Total PP	1.000	.963
Male N	1.000	.962
Female N	1.000	.976
PP Density	1.000	.982
Household N	1.000	.882
HH Density	1.000	.961
Slum PP	1.000	.954
Slum Families	1.000	.971
Slum HH	1.000	.965
Slum HH Den	1.000	.782
Expenditure BG	1.000	.587
Property Taxes	1.000	.768
Land Value Taxes	1.000	.686
Signboard Taxes	1.000	.784
Factories N	1.000	.933
Labors Fac.	1.000	.935
Garbage Total	1.000	.625
Residential Area	1.000	.581
Hospital Area	1.000	.770
Religion Area	1.000	.764

Extraction Method: Principle Component Analysis.

contribution of each component to 84.645% of total of explained variance (EV) and corresponding eigenvalue higher than 1 in the data. There presented the factor loadings, each component of which can be delineated as the dimensions of low-income characteristics. Thus, eigenvectors on each extracted component were set and presented by the weighting scores of each original land-cover attributes, which will give information for the PCA explanation (Owen et al., 2006).

The details of Table 4 with the heavily loading shaded in grey, 21 indicators of all eigenvectors are shown in 6 PCs. The loadings analysis is characterized by the highest value of indicators, depending on factors loadings higher than 0.3. These components can be used to assess the low-income characteristics over the range of averaging time periods following socio-economic session. The characteristics of 6 PC categories for BMA site data was interpreted as follows:

The first PC explained over 27.205% the total variance, which dominated the *"personal contribution"* by Total PP, Male N, Female N, Household N, and Garbage Total, and the lowest values of Expenditure BG. The strong relationship was generally accounted for a reduced percentage of remaining variability between the number of population, household unit, and garbage per year in each districts of BMR.

PC2 are explained over 19.969% the total variance, which dominated the *"living density"* by Area Size, PP Density, HH Density, and Slum HH Den, and negative values of Garbage Total. There are accounted and represented by a density association of living elements especially as population, households, and slum/low-income household as a common factor.

PC3 are explained over 13.780% the total variance, which dominated by Expenditure BG, Property Taxes, Land Value Taxes, Signboard Taxes, and Residential Area. There are indicated into the elements of *"expenditure estimation"*.

TABLE 4 THE PCA ANALYSIS LOADING OF MENTALS AND MAJOR ELEMENTS OF SOCIO-ECONOMIC FACTORS AT BMR SITE

Variable	Component					
	PC1	PC2	PC3	PC4	PC5	PC6
Area Size	.194	.938	-.007	.109	.115	.020
Total PP	.954	.061	-.055	.211	.021	.005
Male N	.949	.063	-.079	.226	.028	.002
Female N	.965	.064	-.031	.198	.027	.007
PP Density	.017	.985	-.027	.046	.099	.012
Household N	.881	.078	.261	.147	.067	.076
HH Density	-.004	.975	-.073	.052	.051	-.002
Slum PP	.242	-.041	.078	.941	.000	.058
Slum Family	.201	-.043	.114	.954	-.005	.077
Slum HH	.259	.051	.105	.938	-.010	.058
Slum HH Den	-.028	.832	-.078	-.269	.098	.037
Expenditure BG	.411	.198	.572	.223	-.051	.003
Property Taxes	-.195	-.140	.835	.075	-.017	.086
Land Value Taxes	.081	.036	.813	.059	-.088	.071
Signboard Taxes	.084	-.069	.876	.044	-.029	.044
Factories N	.081	.125	-.065	-.002	.952	-.004
Labors Fac.	.079	.170	-.068	-.014	.946	-.011
Garbage Total	.576	-.353	.296	.006	.267	.097
Residential Area	.048	-.138	.686	.028	.020	.297
Hospital Area	.069	.091	-.181	-.040	-.107	.844
Religion Area	.011	-.030	.163	.208	.099	.826
Initial eigenvalue	5.713	4.194	2.894	2.051	1.693	1.231
% of total variance	27.205	19.969	13.780	9.769	8.062	5.860
Cumulative percentage	27.205	47.174	60.954	70.723	78.785	84.645

Extraction Method: Principle component analysis. Rotation Method: Varimax with Kaiser Normalization.

The rotated component matrix converged in 6 iterations

PC4 are explained over 9.769% the total variance, which dominated the *"slum/low-income condition"* by Slum PP, Slum Families, and Slum HH, which may suggest as a natural of slum/ low-income settlement factor.

In addition, Factories N were found to associate with Labors Fac. in PC5, which explained over 8.062% the total variance, dominating the *"industrial sources"*, which correlated with the spatially aspects of socio-economical vulnerability of factories indices in BMR. The sixth components were closely associated with the total variance of PC6, which explained over 5.860%. Thus, there was dominated the "facility sources" that had excessed input of analysis into Hospital Area, and Religion Area factors.

The normalized index such as the combination of PC1, PC2, PC3, and PC4 relatively explained 70.723% of the total variance with more evenly distributed PC5 and PC6 scores. The vulnerability of slum / low-income settlements (Slum HH Den., Slum PP., Slum Family, and Slum HH.) was extracted from PC2 and PC4. Thus, the relationship of principle component score plots between the lowest value of Expenditure BG (PC1) was characterized with the highest values of PC3 (Fig. 5) and the Garbage Total factors of high factor loading in PC1 was characterized with the positive values of PC2 (Fig. 6). From comparison of two plots of Fig. 5 and Fig. 6, we found that the closer the direction of the line (PC1) is the more indicators are characterised within negative dataset of PC2 and PC3.

These results leads to carefully consideration on the system under this study. Particularly, the normalized socio-economic can be more easily related to the

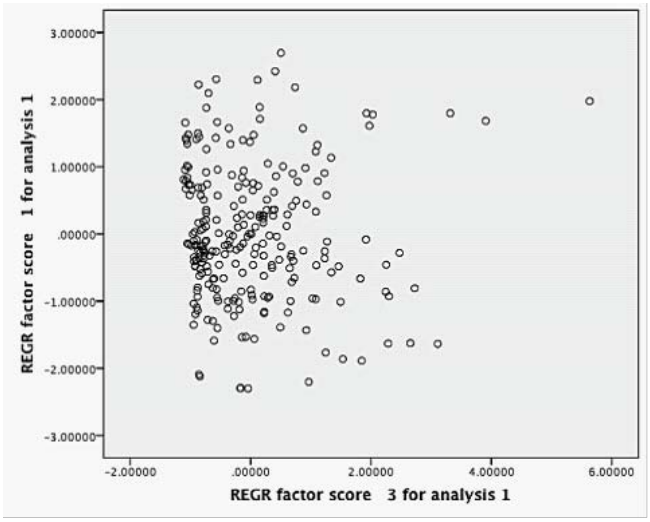

FIG. 5 PRINCIPLE COMPONENT SCORE PLOT OF BETWEEN PC1, AND PC3 (EV% = 40.985)

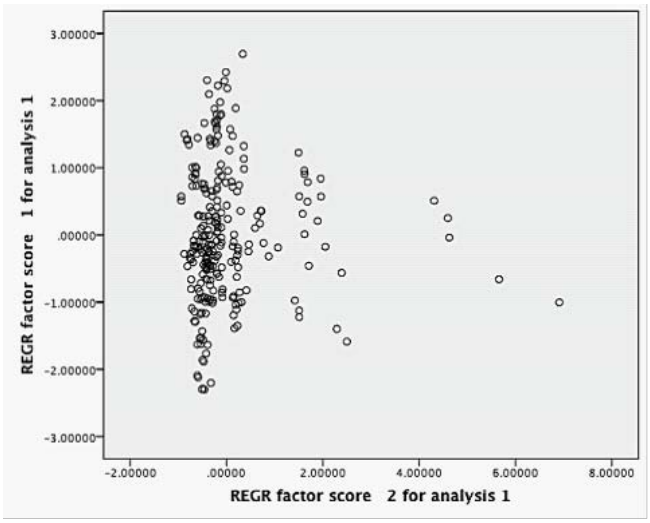

FIG. 6 PRINCIPLE COMPONENT SCORE PLOT BETWEEN PC1, AND PC2 (EV% = 47.174)

vulnerability indices of low-income settlement characteristics from PCA technique. The treatment of PCs loading has provided a multivariate view of study site, which is necessary in order to better understand the above interrelated separations.

Conclusions

This study offered the multivariate statistical method, which is proposed for high-resolution datasets based on PCA assessment of socio-economical vulnerability of the low-income settlement characteristics, with the different characteristics by different types of vulnerability. Using PCA packages to generate aggregate availability of algorithms, the multiple scales of PCs represented a useful tool for analyzing a large multivariate of data set. Moreover, the GIS analysis also concerned the underlying causes of identifying area characteristics and impacts of socio-economical vulnerability factors. An all-round considerations of indicators to highlight more specific recently concerns from the sites viewpoint especially in 2009 has been made, as shown in FIG. 7. The multiple spatial scales of PCA were analyzed and represented by the small number of socio-economical vulnerability in specific geographical locations of BMR.

Most important results have established a comprehensive methodology framework for regionalization of the large-scale area toward the low-income settlement characteristics in BMR, using the socio-economical data, which is provided by dynamic concept and spatial map. In summary, it could be directly refered and adapted into urban planning and design guideline level as well as the urbanization and

low-income approaches, combining and realizing to the policy theoretical development and practical guidance to many other situations.

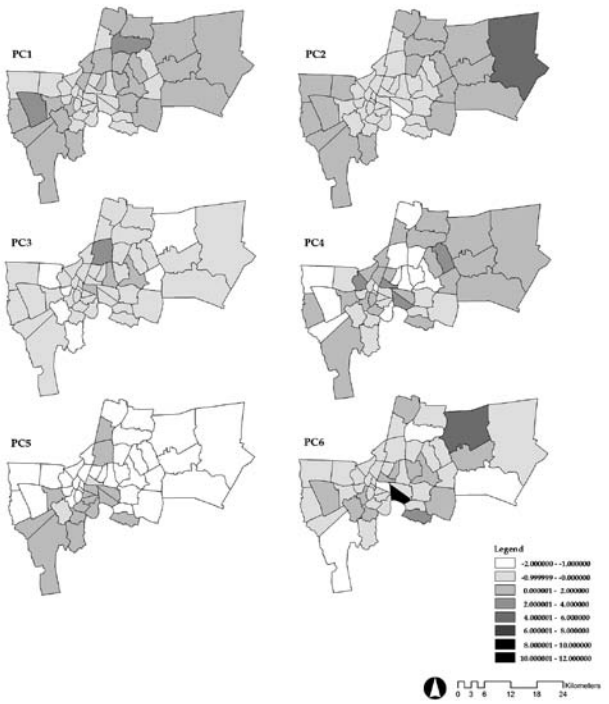

FIG. 7 NORMALIZED MAPS OF SOCIO-ECONOMICAL VULNERABILITY BASED ON PCA INDICES IN 2009

For the policy and urban planning guideline, the spatial maps had suggested the tension and absolute poverty of living condition that the socio-economical vulnerability sources across "personal contribution"on PC1, "living density" on PC2, "expenditure estimation" on PC3, "slum/low-income condition" on PC4, "industial sources" on PC5, and "facility sources" on PC6. All spatially vulnerability maps dominated the highest interesting area in the eastern and western of region, while slum/low-income condition (PC4) also indicated highlights in some area of CBD reference to relatively high vulnerability type of PC5 and PC6.

From this study, PCA had been used for the extraction factors between social and economic system in the era of rapid urbanization, while the PCs loading provided the significantly variables. Within many cities, future studies should be further integrated and enhanced for the understanding of accuracy and validity of the low-income settlement characteristics (LISC) modelling system with classification and evaluation tools, which will helpfully cover more complex, together on those aspects of unique environmental, social, economical position in the specificities and also considering with homologous indices.

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